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THESIS

INTERCONNECTING LOCALTALK AND TOKEN RING NETWORKS IN SOFTWARE METRICS LAB, INGERSOLL 158

by

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March, 1995

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Within DOD, there exists many different network platforms and configurations. Managing multiple platforms with different protocols, configurations, and applications is a challenging task for a network manager. A possible solution to efficiently manage these multiple platforms is to allow platforms to share resources, databases, and applications. In the Software Metrics Lab at the Naval Postgraduate School two disparate networks exist: a LocalTalk network and an IBM Token Ring network. Interconnection and interoperability between these networks is possible. This thesis uses a combination of three interconnection approaches: protocol function, network access, and network services approach to design an interconnected network. This thesis provides a proposed solution and an implementation plan , along with estimated hardware and software costs. The methodology used to reach a solution is a combination of a literature review on network connectivity, and interviews with consultants, technical editors of network magazines, and the school's cognizant lab managers. The results of this thesis can be applied to other DOD activities that manage different network platforms.

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INTERCONNECTING LOCALTALK AND TOKEN RING NETWORKS IN SOFTWARE METRICS LAB, INGERSOLL 158

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ABSTRACT

Within DOD, there exists many different network platforms and configurations. Managing multiple platforms with different protocols, configurations, and applications is a challenging task for a network manager. A possible solution to efficiently manage these multiple platforms is to allow platforms to share resources, databases, and applications. In the Software Metrics Lab at the Naval Postgraduate School two disparate networks exist: a LocalTalk network and an IBM Token Ring network. Interconnection and interoperability between these networks is possible. This thesis uses a combination of three interconnection approaches: protocol function, network access, and network services approach to design an interconnected network. This thesis provides a proposed solution and an implementation plan , along with estimated hardware and software costs. The methodology used to reach a solution is a combination of a literature review on network connectivity, and interviews with consultants, technical editors of network magazines, and the school's cognizant lab managers. The results of this thesis can be applied to other DOD activities that manage different network platforms.

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I. INTRODUCTION

A. PURPOSE AND OBJECTIVE

1. Purpose

The purpose of this paper is to propose a solution that can interconnect two disparate networks. In this case, a LocalTalk network and a Token Ring network situated in Naval Postgraduate School's Software Metrics Lab, Ingersoll 158 (room IN 158).

2. History

A PC-Macintosh network was operational in the networks laboratory , Ingersoll 224 (room IN 224), from 1988 to 1993. The PC (IBM clone computers) and Macintosh equipment in room IN 224, were obsolete and were excessed by 1993. At about the same time, new PC and Macintosh equipment was installed in room IN 158, with PCs connected to the Macintosh LocalTalk Network, as had been the case in room IN 224. However, it was found that the Transcendental Operating System (TOPS), that had been used for PC-Macintosh communication was not compatible with the new Macintosh hardware and its operating system called System 7. Therefore, there is a need to identify a way for PC and Macintosh machines to communicate. The network manager will have an easier task in managing these networks if applications, resources, and databases can be shared between these different networks.

3. Department of Defense Relevance

Rapid growth in network technology have resulted in many network products and standards. There exists many different network platforms and configurations within the Department of Defense. A common scenario, a department uses a network consisting of Macintosh computers while another uses a network consisting of IBM PC or clone computers. Managing separate multiple platforms with different protocols, configurations, and applications is a challenging task for a network manager. A possible solution to manage these multiple platforms is to allow platforms to share resources, databases, and applications. Interconnecting disparate networks is possible.

B. RESEARCH QUESTIONS

Schneidewind [Ref. 1] has described several interconnection issues. This paper will answer four of those issues as they relate to interconnecting LocalTalk and Token Ring networks in Software Metrics Lab [Ref. 1]:

- What protocols would be used to interconnect the two networks?
- How should the two networks communicate?
- How should the two networks in the software metrics lab be physically attached?
- What are the costs involved in interconnecting the two networks?

C. METHODOLOGY

1. Network Access, Network Service, and Protocol Function

There are three basic approaches to solve the interconnection problem. They are: network access, network services, and protocol functions. A combination of these approaches is necessary to interconnect two disparate networks effectively. Network access approach involves the physical and interfacing aspects of interconnection which are the first three layers of the ISO model. Network service approach looks at what network services and resources can be obtained by a user network. Network service approach

emphasizes interconnection at the higher levels of the ISO model. The protocol function approach's primary objective is to interconnect two diverse networks through protocol conversion. Schneidewind [Ref. 1], provides detail description, advantages, and disadvantages of the three approaches to interconnecting networks. [Ref. 1]

2. Literature Review and Interviews

A literature review on network interconnection was conducted. In addition, interviews (meetings, telephone interviews, and communication via electronic mail) with System Management Lab Staff, network consultants, Macintosh LAN Administrator of Naval Postgraduate School, technical editor *Network Computing* magazine, and editor of a network help desk of *Network World* magazine, were conducted to help in solving the problem of interconnecting the two networks in room IN 158. A proposed solution to interconnect LocalTalk and token ring networks in room IN 158 was based on literature reviews and interviews.

D. ORGANIZATION OF THESIS

This paper is organized in five chapters.

- Chapter I, "Introduction," provides purpose of this thesis and general information concerning Department of Defense relevance and methodology used in determining a solution.
- Chapter II, "Background," provides the current network configuration of the LocalTalk and token ring network and the problem statement.
- Chapter III, "Proposed Network Configuration," provides a proposed solution utilizing the three basic approaches: protocol function, network access, and network services.
- Chapter IV, "New Network Layout and Costs," provides network map of the proposed solution, general hardware and software costs, and a proposed implementation plan..
- Chapter V, "Conclusions and Recommendations," provides answers to the research questions and recommendations for further research.

II. BACKGROUND

A. INTRODUCTION

1. Network Abbreviations

There are some network abbreviations which will be used throughout this thesis. The following conventions will be used [Ref. 2]:

- 0TR - Token Ring Network in Systems Management Lab, room IN 250.
- 4TR - Token Ring Network in Systems Management Lab, room IN 224.
- 8AP - AppleShare Network in Software Metrics Lab (SML), room IN 158.
- 8TR - Token Ring Network in SML.
- N3 - File server for 0TR
- N6 - File server for 0TR
- TN3 - File server for 4TR.
- TN4 - File server for 8TR.
- TN6M - File server for 4TR.

2. Software Metrics Lab

The SML, room IN 158, has two local area networks (LANs), that are used as network test beds: 8TR and 8AP for this thesis. Current configurations of these networks are covered in the next section.

B. CURRENT NETWORK CONFIGURATIONS

The first step in designing or considering to upgrade a network is to construct a network map. A map reflects the current network topology and shows the workstations and hardware that make up the network. Information retrieved from a map will help in understanding the current network and future design of the network [Ref. 3, p. 29]. Described in the next subsections is a description of the 8TR and 8AP, and network maps depicting network topology and configuration.

1. Token Ring Network

The token ring network 8TR complies with the IEEE 802.5 standard, early token release. Early token release (ETR) option is when a free token is released as soon as the sender transmits a busy token. This option allows transmission speeds to reach up to 16 Mbps [Ref. 4, p. 10; Ref. 5, p. 46]. The network, 8TR, is a logical ring, physical star topology running IBM PC LAN Program Version 1.3, LAN Support Program (LSP), Version 1.26, and DOS Version 6.0. There are seven IBM clone personal computers (PC), connected by an eight port multi-access unit (MAU), with TN4 designated as a dedicated network server. This token ring network's rated transmission speed is 16 Mbps. Figure 2.1 depicts the network map of 8TR. [Ref. 2, p. 9]

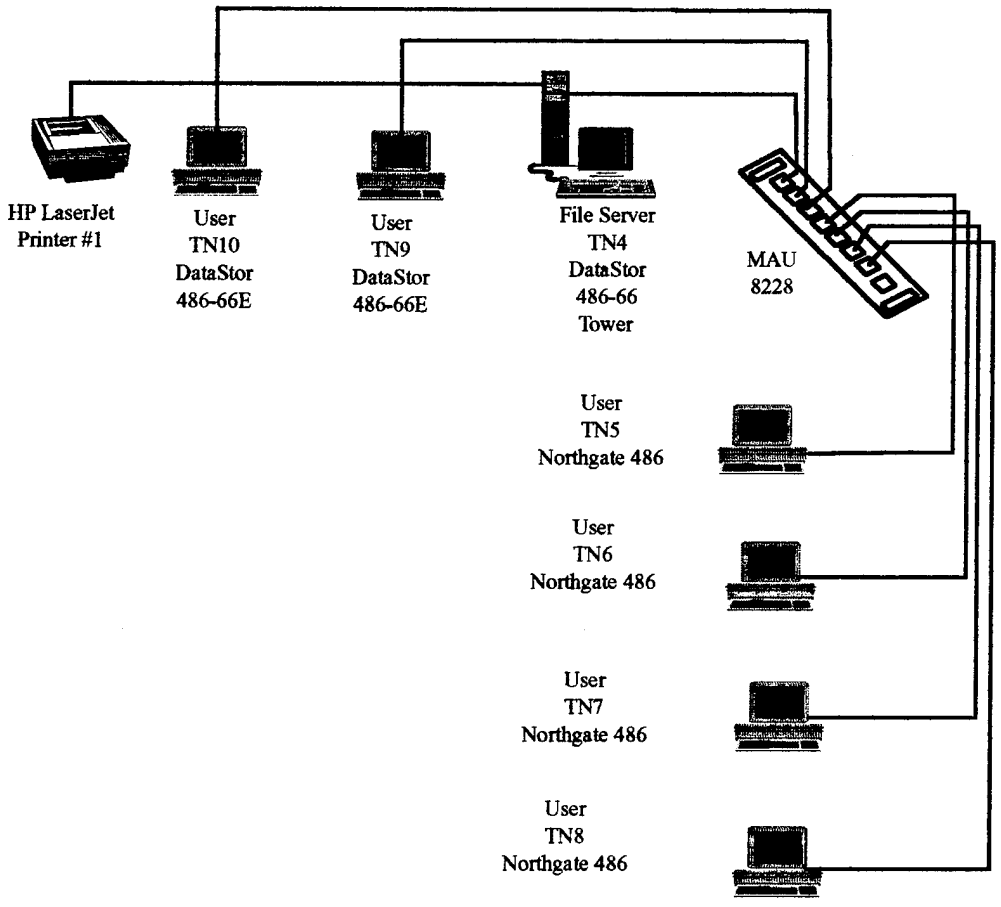

Figure 2.1. Token Ring Network, 8TR, After [Ref. 2].

2. Macintosh LocalTalk Network

The Macintosh computers are configured in a LocalTalk network, designated 8AP, and designed to run AppleTalk protocols. The machines are in a daisy-chain bus topology running AppleShare. Contrary to the token ring network 8TR, 8AP is a carrier sense multiple access collision avoidance network. The three Macintosh IIfx, three Quadra 950, and Apple LaserWriter are connected together by an AppleTalk connector kit. This network's rated transmission speed is 230.4 Kbps over shielded twisted pair cables. One of the Quadra 950 machines, designated AP0, is a dedicated file server. Figure 2.2 depicts the network map of 8AP. [Ref. 2, pp. 49-51; Ref. 5, p. 156; Ref. 6, p. 127]

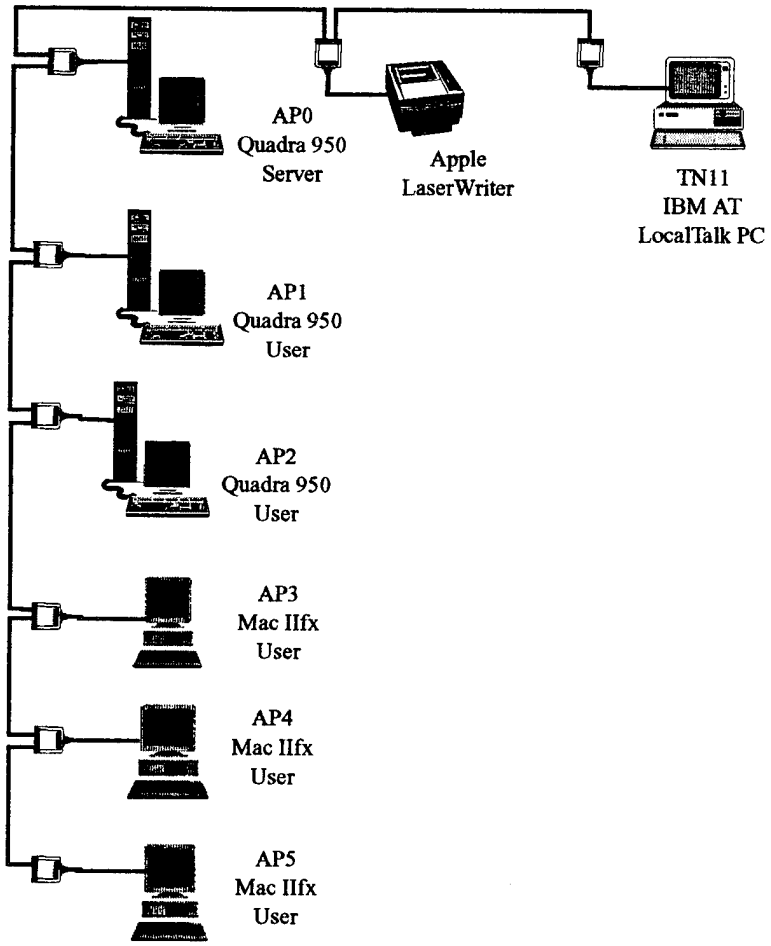

Figure 2.2. LocalTalk Network, 8AP, After [Ref. 2].

3. Current PC-Mac Connectivity

The current PC-Mac interconnection configuration is also indicated in Figure 2.2. The PC (IBM AT model), designated TN11, is physically connected to the LocalTalk network by a PC LocalTalk interface card and AppleTalk connector kit. AppleShare PC software is loaded in TN11 to provide the logical connection. It allows the PC to log on to AP0, view its directories, copy Mac text files, and print on the Apple LaserWriter. The software allows AP0 to copy files and subdirectory of files [Ref. 2, p. 52]. The PC operating system loaded in TN11 is DOS 3.3. PC-Mac connectivity tests proved unsuccessful when a later version of DOS was installed in TN11. Also, only four Macintosh computers (AP0, AP1, AP2, and AP3) can share resources with TN11 [Ref. 7].

C. PROBLEM STATEMENT

The problem statement is straightforward. Find a cost effective solution to connect 8TR and 8AP. Connection should allow the transfer of files between 8TR and 8AP. Also, solution must include future connection to the campus backbone with electronic mail (email), file transfer protocol (ftp) and remote terminal emulation (telnet) capability to access the Internet, mainframe-based computer (Amdahl 5995-700A), and SUN file servers located throughout the Naval Postgraduate School Campus. There are additional requirements due to budgetary constraints [Ref. 8; Ref. 9]:

- 8TR will continue to use DOS 6.0, PCLP 1.3, and LSP 1.26.
- 8TR will remain a 16Mbps token ring network.
- 8AP will remain a LocalTalk network. Migration to Ethernet can be considered once connection between LocalTalk 8AP and 8TR is successful.

III. PROPOSED NETWORK CONFIGURATION

A combination of the three basic approaches of interconnection was utilized to determine a solution. The problem statement was divided into three categories: protocol function, network access, and network services.

A. PROTOCOL FUNCTION APPROACH

A primary objective is to interconnect two diverse networks, 8AP and 8TR, through a standard protocol. This is accomplished by using Transmission Control Protocol/Internet Protocol, known as TCP/IP, and using a gateway for protocol conversion.

1. TCP/IP Suite for Interconnection

TCP/IP was developed in the late 1960s to support communication among different computer systems that were working on projects for the government's Advanced Research Projects Agency Network, ARPAnet [Ref. 10; Ref. 11; Ref. 12]. Meyer and Zobrist [Ref. 12] provides a good description of the TCP/IP layers. It could be noted that like the Open Systems Interconnection (OSI) Reference Model developed by the International Organization for Standardization (ISO), the structure of layers is such that simple and streamlined network services exist at the lowest layers while complex functions exist at the higher layers. The IP layer is the layer above the medium access control (MAC), logical link layer (LLC), and physical layers of a network. The IP layer provides the rules concerning which datagrams or packets are transmitted and received over a network. The IP provides intelligent routing services designed to move a datagram closer to its destination. However, the IP layer does not guarantee reliability and error free transmission while routing a datagram. Reliable transmission of a datagram is performed by the next higher layer which is called the TCP layer. [Ref. 12]

The TCP layer ensures that a correct datagram is received. If an error occurs during transmission, the TCP layer provides the services to retransmit a datagram until a correct one arrives at its destination. The TCP layer also provides virtual circuit connections. [Ref. 12]

Above the TCP layer exists a set of network applications or utility programs. This is the highest level of the TCP/IP protocol suite. Some common network applications that exist in this layer are ftp, telnet, and email. Figure 3.1 depicts the basic structure of the TCP/IP layers. Additional information on TCP/IP can be retrieved through the Internet [Ref. 12; Ref. 13; Ref. 14].

TCP/IP is a mature protocol. It runs the world's largest network called the Internet. The current trend among operating system software companies is to incorporate TCP/IP into the operating system package. For example, when users purchase the latest version of Apple System 7.5, MacTCP is included in the package [Ref. 6, p. 440; Ref. 15]. Microsoft's Windows NT, Chicago, and Windows for Workgroups include TCP/IP protocols in their operating system package. [Ref. 15; Ref. 16]

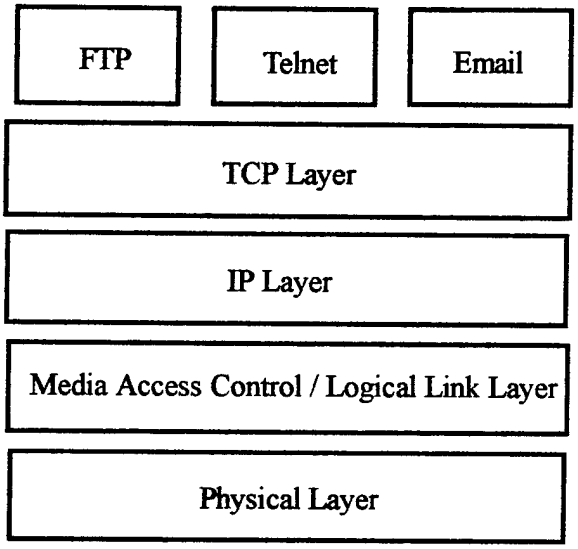

Figure 3.1. TCP/IP Layers. After [Ref. 12].

2. TCP/IP Software for PC and Macintosh

There are many vendors that provide TCP/IP software for both Macintosh and IBM clone computers. TCP/IP software packages are not identical in capability. Reviewing TCP/IP product comparisons and costs will help in making a decision on which software to purchase. Product reviews, comparisons, and costs are available through the Internet and professional network magazines . [Ref. 6, p. 444; Ref. 15; Ref. 17; Ref. 18]

a. PC TCP/IP Software for 8TR

In 8TR, TCP/IP software is not installed in each PC (TN4 through TN10). However, 4TR and 0TR currently have FTP Inc., PC/TCP Software version 2.3 installed in each PC. The logical network configuration of 8TR is the same as 4TR and 0TR. Since 4TR and 0TR have fully functional installations of PC/TCP Software, the same installation could be performed on 8TR. Eight additional copies of PC/TCP Software could be procured and installed in 8TR. This software would provide the TCP/IP layers required for network interconnection with 8AP. Figure 3.2 depicts token ring layers with TCP/IP layers stacked above it.

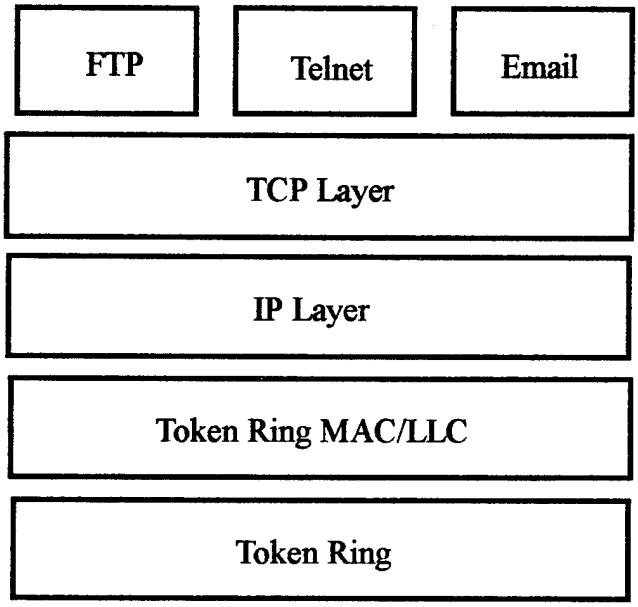

Figure 3.2. Token Ring and TCP/IP Layers.
After [Ref. 5, p. 46; Ref. 6, p. 421; Ref. 12].

b. Macintosh TCP/IP Software for 8AP

MacTCP is Apple's platform for TCP/IP. It serves as a foundation for TCP/IP applications on a Macintosh network. MacTCP works with TokenTalk (Apple's version of IBM Token Ring), EtherTalk, and LocalTalk protocols. MacTCP resides above the Link Access Protocol Layer of AppleTalk protocols and contains basic elements of TCP/IP. Higher level applications are not bundled in MacTCP, but can be procured from commercial vendors. For example, PC/TCP Software has ftp, telnet, and email bundled in its TCP/IP package, but MacTCP does not. This could be a disadvantage compared to TCP/IP software packages that have all levels of TCP/IP protocol suite bundled in its package. Figure 3.3 depicts LocalTalk with MacTCP and TCP/IP applications. [Ref. 6, pp. 438-450; Ref. 15; Ref. 17]

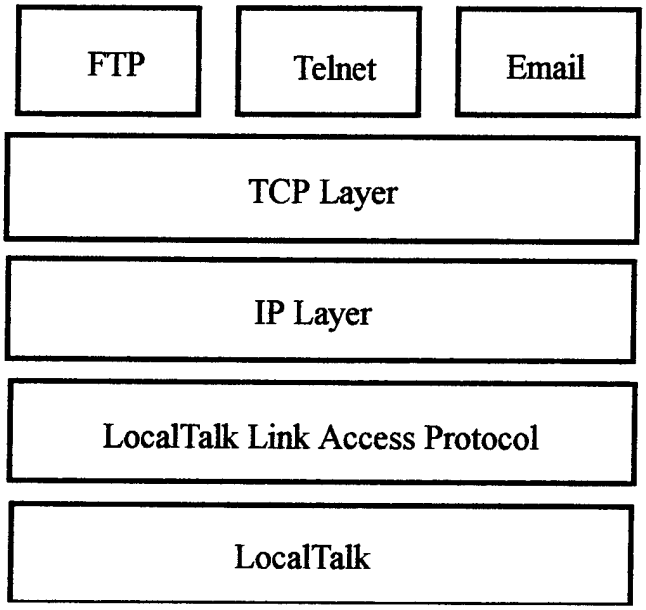

Figure 3.3. LocalTalk, MacTCP, and TCP/IP Applications.
After [Ref. 6, p. 439; Ref. 12]

3. Gateway

Using a gateway to link disparate LANs is also required under the protocol function approach for interconnection. A gateway converts protocols between two different networks and can be classified into three categories: encapsulating routers, transport-level gateways, and application-level gateways. Encapsulating routers take packets from one network and wraps them in packets formatted for transmission to a second network.. Encapsulating routers also perform the reverse process by stripping away packets from a second network and sending the stripped packets to the first network. Transport-level gateways are like encapsulating routers except that they operate at the transport layer. Application-level gateways are used when translation of all seven layers of the OSI reference model are required between disparate networks. [Ref. 2, p. 41; Ref. 6, pp. 427-435; Ref. 19, p. 33]

To convert LocalTalk packets to TCP/IP packets on a Token Ring network, a transport-level gateway is required. Gateways can be special purpose hardware devices or a Macintosh or PC can be converted to a gateway by software. Software gateways are generally less expensive than gateway or router boxes because software gateways run on a pre-existing computer. [Ref. 6, p. 429; Ref. 20]

Dedicated file servers for 8AP can be converted to a gateway by installing three software packages: MacTCP, Apple Internet Router and Apple IP Gateway software. Installing these packages provides routing and conversion capability for LocalTalk packets to TCP/IP packets. The Apple Internet Router provides the software interconnection and routing between LocalTalk, Ethernet, and Token Ring networks, while the IP Gateway acts as a translator between AppleTalk protocols and TCP/IP protocol networks. Figure 3.4 depicts an example of transport-level gateway. [Ref. 6, p. 426; Ref. 20; Ref. 21; Ref. 22; Ref. 23

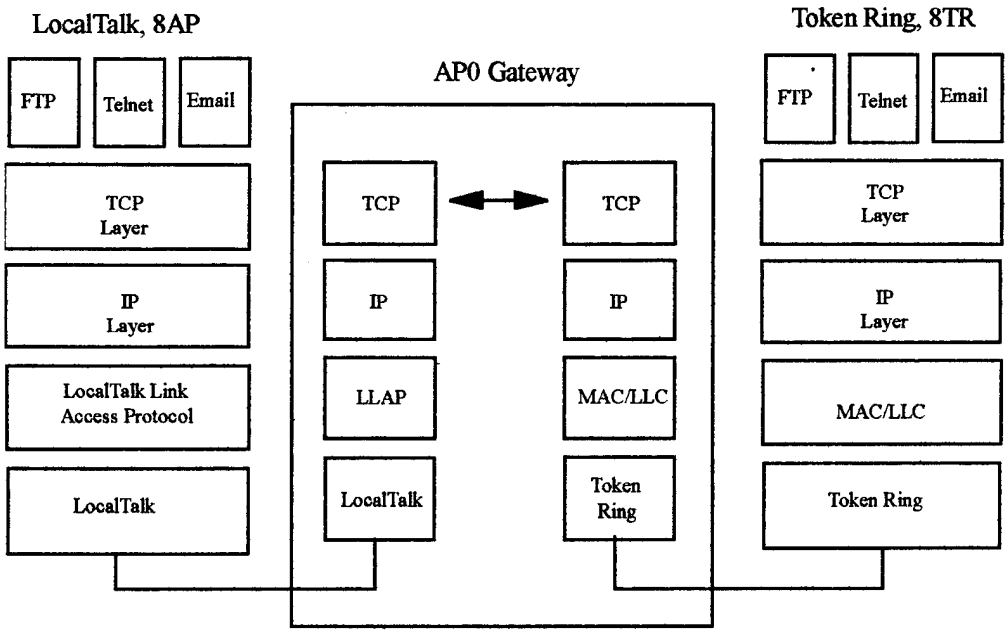

Figure 3.4. Transport-level Gateway. After [Ref. 6, p.432; Ref. 20].

B. NETWORK ACCESS APPROACH

The network access approach to connecting 8AP to 8TR involves the physical connections between AP0 and 8TR. The primary objective is to physically and logically connect AP0, the file server/gateway for 8AP, to 8TR. The token ring network, 8TR, must recognize AP0 as a node in the ring. Since token ring is not built into the Macintosh computers, like LocalTalk is for Macintosh IIfx, and Quadra 950 models, a compatible token ring network interface board (NIC) must be installed in AP0. Apple Token Ring 4/16 NB Cards are available from Apple Computer, Inc., and use an IBM Token Ring chip set, allowing AP0 to interoperate with 8TR at 16 Mbps. A network software installer disk is included with a NIC. This disk includes the token ring drivers that allow the physical and logical connection of AP0 to 8TR. Also, IBM Type 1 shielded twisted pair cable is required to connect the NIC to 8TR MAU. [Ref. 1; Ref. 24; Ref. 25]

C. NETWORK SERVICE APPROACH

The network service approach involves the interconnection between 8TR and the campus backbone. The token ring networks, 4TR and 0TR, are connected to the campus backbone via patch cables from MAU #3 in 4TR to a router in the computer center. The token ring network, 0TR, has access to the campus backbone because 0TR is connected to 4TR by patch cables extending from 0TR MAU #4 ring out socket to 4TR MAU #3 ring in socket, and by patch cables extending from 4TR MAU #1 ring out socket to 0TR MAU #1 ring in socket [Ref. 2, p. 11]. Multiple segments of patch cables exist between the connection of 4TR and 0TR. Access to the campus backbone from 8TR can be accomplished by tapping in to one of the segments that exist between 4TR and 0TR. Figure 3.5 depicts the connection between 0TR, 4TR, and 8TR. The TCP/IP protocol suites that can be installed in 8TR and 8AP will provide telnet, email, and ftp functionality across the campus backbone and the Internet. [Ref. 1; Ref. 2, pp. 9.1-11]

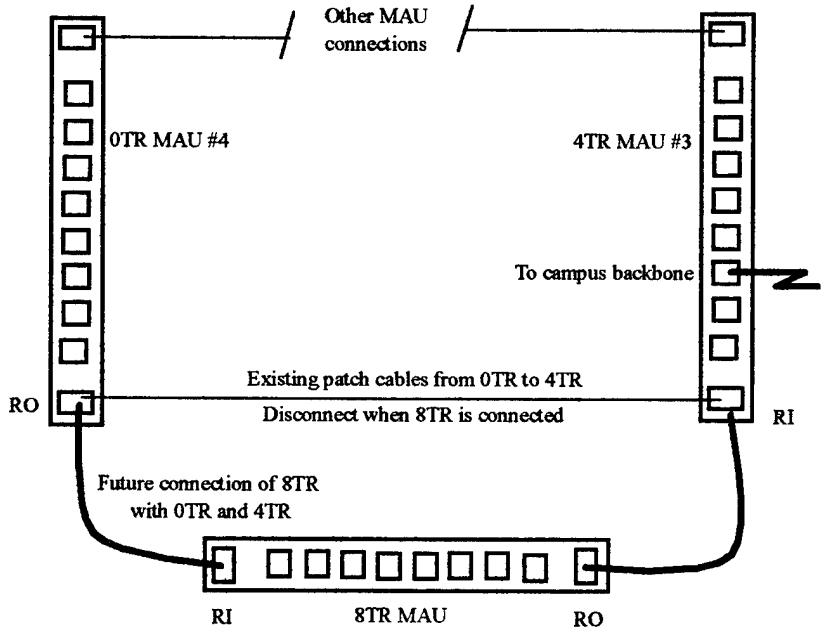

Figure 3.5. MAU Connections. After [Ref. 2, pp. 9.1-11].

IV. NEW NETWORK LAYOUT AND COSTS

A. NETWORK MAP

1. Proposed Network Layout

A proposed network layout connecting 8AP and 8TR is depicted in Figures 4.1 and 4.2. This design is based on a combination of protocol function, network access, and network service approaches described in Chapter III. The LocalTalk network, 8AP, is connected to 8TR via a token ring NIC and cable connection from AP0 to 8TR MAU. The logical connection of AP0 to 8TR is supported by token ring drivers. The file server, AP0 in Figure 2.2, is converted to a gateway to allow conversion between TCP/IP protocols in both token ring and LocalTalk networks. Access to the campus backbone is accomplished by connecting 8TR to 4TR and 0TR. This connection would also allow 8AP access to the campus backbone. [Ref. 1; Ref. 2; Ref. 6; Ref. 7; Refs. 26-37]

2. Hardware and Software Costs

Estimated hardware and software costs for configuration depicted in Figures 4.1 and 4.2, are listed in Table 4.1. Robbins and Tittel [Ref. 3, pp. 52, 197-201], provide guidance on budgeting costs for installing and upgrading networks. Costs include materials such as crimping tools, pins, and connectors; network hardware; labor; and testing. Since testing and debugging is an important stage in making sure the network installation is successful, only one TCP/IP software package for each network, 8TR and 8AP, is recommended to be purchased. Once testing the connections and applications is successful on one user computer, then additional TCP/IP software packages can be procured for installation on the rest of the computers in 8AP and 8TR.

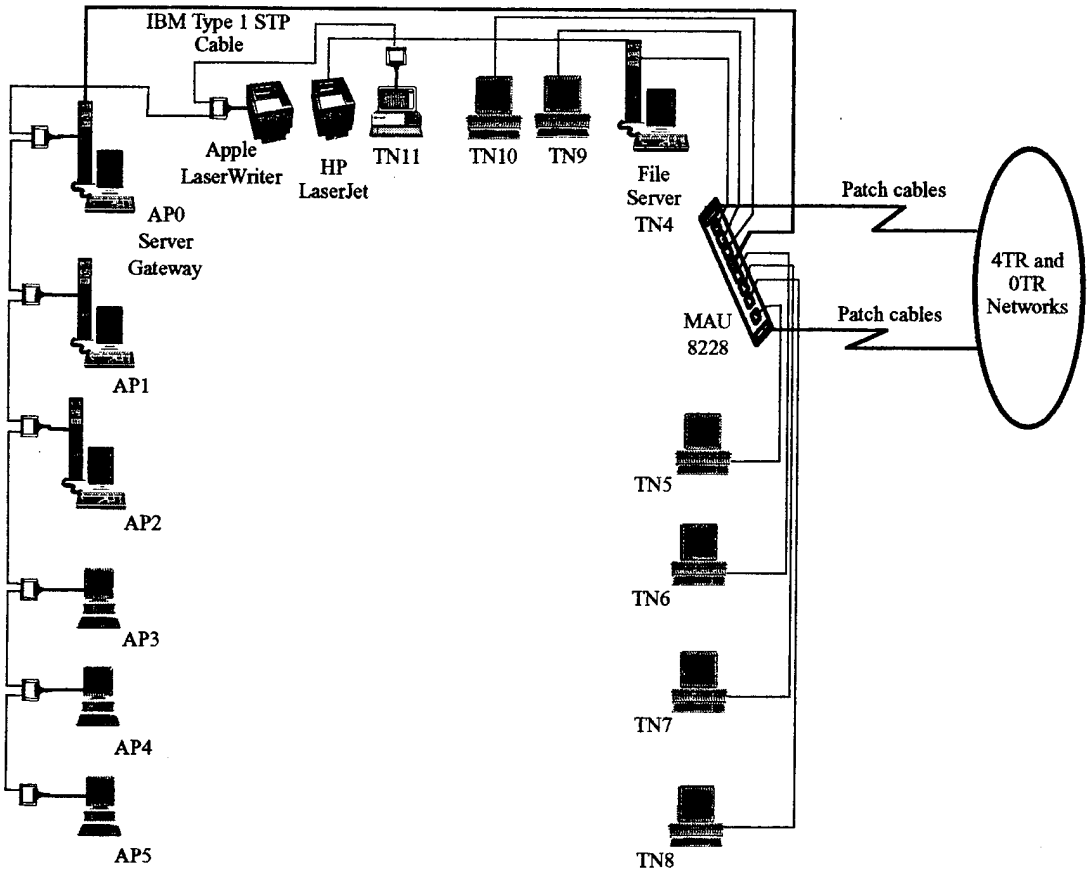

Figure 4.1. Interconnection of 8TR and 8AP.
After [Refs. 1, 2, 6, 7, 26-37].

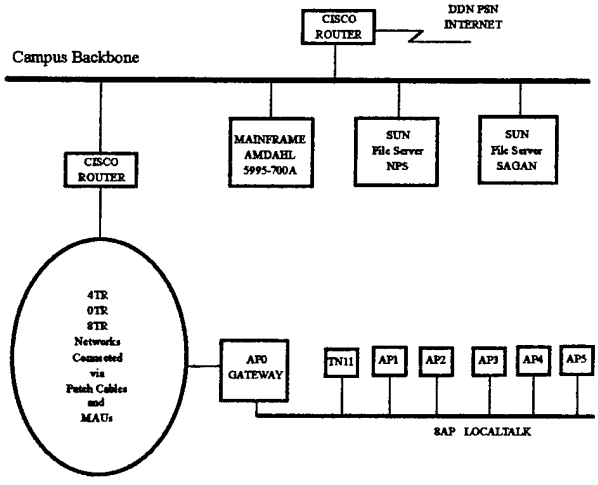

Figure 4.2. 8TR and 8AP Connection to Campus Backbone.
After [Refs. 1, 2, 6, 7, 26-37].

Hardware		Estimated costs
Token Ring NIC NuBus 16Mbps for AP0		$364.00
STP Type 1 Cable, 8 ft. segment (connect AP0 to 8TR) @ $26.50 ea.	1 ea.	$ 26.50
Patch Cables, 150 ft. segments (connect 8TR to 4TR) @ $74.00 ea.	4 ea.	$296.00
Software		
MacTCP @ $32.00 ea.	2 ea.	$ 64.00
Apple Internet Router Connectivity Package @ $301.00 ea.	1 ea.	$301.00
Apple IP Gateway @ $170.00 ea.	1 ea.	$170.00
TCP/IP Software Package for 8TR @ $200.00	1 ea.	$200.00[1]
TCP/IP Application Software Package for 8AP @ $150.00	1 ea.	$150.00[2]
Estimated Total Costs		$1571.50
1. Currently, Naval Postgraduate School, Systems Management Curriculum has site license for FTP Inc., PC/TCP software.		
2. Invest in one TCP/IP application software for Macintosh to test connections before buying the rest for further installation in all machines on LocalTalk network, 8AP.		

Table 4.1. Estimated costs. After [Refs. 38-40]

B. PROPOSED IMPLEMENTATION PLAN

Once decisions are made as to what needs to be installed and items have been purchased, the next step is to make installation preparations of the new network configuration by devising an installation plan. When preparing an installation plan, there are some factors to consider:

- order of installation and which computers and networks to hook up first.
- incremental testing of physical and logical connections to make sure connections are working properly. [Ref 2, p. 55; Ref. 3, pp. 95-104]

The following sections provide a general installation plan that could be used to implement the LAN configuration depicted in Figures 4.1 and 4.2. Working with one network at a time is recommended. For example, work on connections and software needed on 8TR first. Once testing connections on 8TR are successful, then proceed on installations connecting 8AP.

1. Connecting 8TR to 0TR and 4TR

a. Physical and Logical Connection

(1) Route patch cables from 8TR to connect to patch cable segments of 0TR and 4TR as depicted in Figure 3.5.

(2) Test connections by checking if user computers of 8TR can access resources of file servers in 0TR and 4TR. [Ref. 41]

(3) Test connections by checking if user computers of 0TR and 4TR can access resources of file server in 8TR. [Ref. 41]

(4) Once tests are complete, go to installation of PC/TCP software and test connections of 8TR to campus backbone.

b. Installation of PC/TCP Software

(1) Establish IP addresses for TN4 and one user computer in 8TR. For example, TN9 could be used.

(2) Install PC/TCP software in TN4 and TN9.

(3) Test ftp connections of TN4 and TN9. Testing ftp application could be accomplished by first designating a ftp server computer in 0TR and in 4TR and test ftp applications from TN4 and TN9 to designated ftp servers. Also, test could include setting TN4 and TN9 to ftp server mode so that the ftp application could be tested from user computers in 0TR and 4TR. Also, test could include testing ftp application from TN4 and TN9 to mainframe and other ftp servers in the Internet. If ftp tests are successful, next test telnet capabilities from TN4 and TN9. [Ref. 2]

(4) Test telnet connection for TN4 and TN9. Since DOS is not a multitasking operating system, telnet tests from TN4 and TN9 to computers in 0TR and 4TR are not feasible. Testing telnet application from computers in 0TR and 4TR to TN4 and TN9 is also not feasible. However, telnet to mainframe, unix workstations, DDN NIC, and other designated telnet servers could be conducted. If telnet tests are successful, then test email capabilities. [Ref. 2]

(5) Test email capability of TN4 and TN9. Testing email application from TN4 and TN9 to a computer in 0TR and 4TR could be performed by first setting a computer in 0TR and 4TR in mail server mode. Next, send email from TN4 and TN9 to designated mail server computers in 0TR and 4TR. Test could include sending email to other accounts such as mainframe and unix accounts on campus backbone network. Also, test could include sending email from computers in 0TR, 4TR, mainframe accounts, and unix accounts to TN4 and TN9. [Ref. 2]

(6) If steps (3) through (5) are successful, repeat steps (1) through (5) for the remaining computers in 8TR.

2. Connecting 8AP to 8TR

a. Physical and Logical Connection for Token Ring

(1) Install Token Ring NIC in AP0.

(2) Attach token ring cable from AP0 to 8TR MAU.

(3) Load token ring drivers in AP0.

(4) Test token ring connection of AP0 to 8TR.

b. Load TCP/IP Software in AP0

(1) Establish IP address for AP0.

(2) Install MacTCP in AP0.

(3) Install Apple Internet Router.

(4) Install Apple IP Gateway.

(5) Install TCP/IP application software.

(6) Test TCP/IP connection of AP0 to 0TR, 4TR, and 8TR. Test procedures used in testing ftp and email applications for TN4 and TN9 could be applied here.

(7) Test TCP/IP connection of AP0 to mainframe, other servers in campus backbone, and the Internet. Test procedures used in testing ftp, email, and telnet applications for TN4 and TN8 could be applied here.

(8) If steps (1) through (7) are successful, start testing one user computer in 8AP. For example, AP1 could be used.

c. 8AP TCP/IP Installation

(1) Establish IP address for a test computer in 8AP. For example, AP1 could be used as a test computer.

(2) Install MacTCP in AP1.

(3) Install TCP/IP application software in AP1.

(4) Test TCP/IP connection of AP1 to 0TR, 4TR, and 8TR. Test procedures used in testing ftp and email applications for AP0 could be applied here.

(5) Test TCP/IP connection of AP1 to mainframe, other servers in campus backbone, and the Internet. Test procedures used in testing ftp, email, and telnet applications for AP0 could be used here.

(6) If steps (1) through (5) are successful, repeat steps (1) through (5) for the remaining computers in 8AP.

The above installation plan follows an incremental installation approach. First wiring and physical connections are installed and tested, followed by incremental installation and testing of servers and user computers. Installing the network in discrete stages provides the network administrator and manager a way to quickly pinpoint problem areas. For example, if incremental installation and testing procedures were followed and a problem in the network exists, the cause of the problem is associated with whatever step was performed when the problem surfaced. Incremental installation can help in isolating the problem and pinpointing where to begin troubleshooting. In addition to incremental

testing, multi-user testing could be conducted. Once the network is fully functional, conduct tests with many users simultaneously accessing TCP/IP applications on both 8AP and 8TR. These tests could help in determining performance characteristics and problems with the new network. [Ref. 2; Ref. 3, pp. 102-105]

V. CONCLUSIONS AND RECOMMENDATIONS

A. REVIEW OF RESEARCH QUESTIONS

1. Research Question 1

What protocols would be used to interconnect the two networks? To interconnect 8AP with 8TR, the two main protocols to consider linking is the Token Ring Protocols of 8TR and the AppleTalk Protocols of 8AP. From a network access approach, installing a token ring NIC board in AP0 along with associated Link Access Protocols for token ring is needed. This connection and associated protocols in AP0 will provide token ring connectivity between AP0 and 8TR. [Ref. 24; Ref. 26; Ref. 28; Ref. 30; Ref. 31; Ref. 34]

From a protocol function approach, TCP/IP suite of protocols could be used to interconnect 8AP with 8TR. This is accomplished by installing TCP/IP software in all machines in 8AP and 8TR. Also, a gateway/router is needed to convert and route TCP/IP packets through 8AP and 8TR. [Ref. 15; Refs. 21-22; Refs. 27-37]

2. Research Question 2

How should the two networks communicate? Communication between 8AP and 8TR would be accomplished by ftp and email applications. To accomplish this, computers in 8AP and 8TR must be set up as file servers and mail servers. From a network service approach, TCP/IP configured in 8TR and 8AP machines will provide ftp, telnet, and email capability to other servers connected to the campus backbone and the Internet. Computers in 8TR and 8AP could communicate between each other by utilizing the services offered by servers connected to the campus backbone and the Internet. For example, a mainframe or unix account could be established where users in 8TR and 8AP can access, retrieve, edit, upload ,and download data files or programs needed for both networks. [Refs. 26-37]

3. Research Question 3

How should the two networks in the software metrics lab be physically attached? The proposed configuration attaches AP0 to 8TR MAU using a NIC for token ring and STP cabling. This physically connects 8AP with 8TR. [Ref. 26; Ref. 28; Ref. 30; Ref. 31; Ref. 34]

4. Research Question 4

What are the costs involved in interconnecting the two networks? Associated hardware and software costs to build a test network is under $2500.00. Most of the cost is in converting AP0 to a software gateway/router. Hardware and software costs associated with AP0 includes: token ring NIC, STP cable, token ring drivers, Apple Internet Router Software, Apple IP Gateway Software, MacTCP, and TCP/IP application package. Since incremental installation approach is used, only one set of TCP/IP software package is needed for testing. For example, purchase MacTCP and TCP/IP application software for AP0 and one user computer in 8AP first. If the tests are successful, then consider buying TCP/IP software for remaining computers in 8AP. The same practice could be applied to upgrading 8TR to a TCP/IP package. There are hidden costs such as labor, training the network administrator in the various software packages, and time spent in testing that could be associated with implementing this network installation. Those costs are not reflected in Table 4.1.

B. RECOMMENDATIONS

1. Recommendation 1

Obtain funds to procure necessary hardware and software to test proposed configuration depicted in Figure 4.1.

2. Recommendation 2

As a follow-on thesis, implement proposed configuration. Implementation could begin by first connecting 8TR to 0TR and 4TR. Then work on connecting 8AP to 8TR as depicted in Figure 4.1. Timing and performance tests results could be included in thesis.

3. Recommendation 3

As a follow on thesis, consider converting 8AP from LocalTalk to an Ethernet network. The rated transmission speed of Ethernet is 10 Mbps compared to LocalTalk's rated transmission speed of 230 Kbps. Also consider upgrading the operating system in Macintosh computers from System 7.1 to System 7.5. With this upgrade, MacTCP would be acquired as part of System 7.5.

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